Human Spaceflight Capabilities

Computational Model for Spacecraft/Habitat Volume (Spacecraft Optimization Layout and Volume (SOLV))

Completed Technology Project (2014 - 2017)

Project Introduction

A key design challenge for future long-duration exploration missions is determining the appropriate volume of a spacecraft/habitat to accommodate habitability functions and ensure optimal crew health, performance, and safety. Because spacecraft/habitat volume directly drives mass and cost, this information is needed early in the design process. This proposal is in response to the NASA Research Announcement (NRA) NNJ13ZSA002N A.2.i: Computational Modeling and Simulation for Habitat/Vehicle Design and Assessment, and it addresses the Human Research Program (HRP) Program Requirements Document (PRD) Risk of Incompatible Vehicle/Habitat Design. The objective of this proposal is to develop a constraint-driven, optimization-based model that can be used to estimate and evaluate spacecraft/habitat volume. The computational model development will be completed through four Specific Aims: Estimate spacecraft/habitat volume based on mission parameters and constraints, provide layout assumptions for a given volume, assess volumes based on a set of performance metrics, and inform risk characteristics associated with a volume. To accomplish this, the proposed team has been structured to leverage expertise from diverse fields, including architecture and habitation design, human factors engineering, industrial engineering, optimization-based modeling, and simulation. The proposed work will also leverage technical products developed from the HRP-hosted 2012 Habitable Volume Workshop, as well as work performed in the follow-on exploratory project in 2013, including critical task volume estimations and input/output definitions for the computational model. Lessons learned from the development of the Integrated Medical Model (IMM) developed by the Exploration Medical Capability Element (ExMC) of the HRP will also be applied to the proposed work -- lessons ranging from model development approach to compliance with NASA STD 7009, Standard for Models and Simulation. Model validation and verification will be a continuous process occurring throughout model development. The guidelines of NASA-STD-7009 will be followed in establishing parameters and vetting the credibility of the model at all stages of development. The outcome of the proposed work will directly answer to HRP's Risk of Incompatible Vehicle/Habitat Design and the associated Space Human Factors Engineering (SHFE) SHFE-HAB-09 Gap on technologies, tools, and methods for data collection, modeling, and analysis for design and assessment of vehicles/habitats. A computational model for spacecraft/habitat volume will be an invaluable tool for designers, mission planners, integrators, and evaluators who are shaping space habitats and working toward a truly habitable environment for future long-duration exploration missions.

Anticipated Benefits

Earth industries that are concerned with habitability in confined environments for long durations (e.g., shipping, submarines, oil and gas rigs, Antarctic research stations) may benefit from the task-based approach in development for determining overall volume needs.

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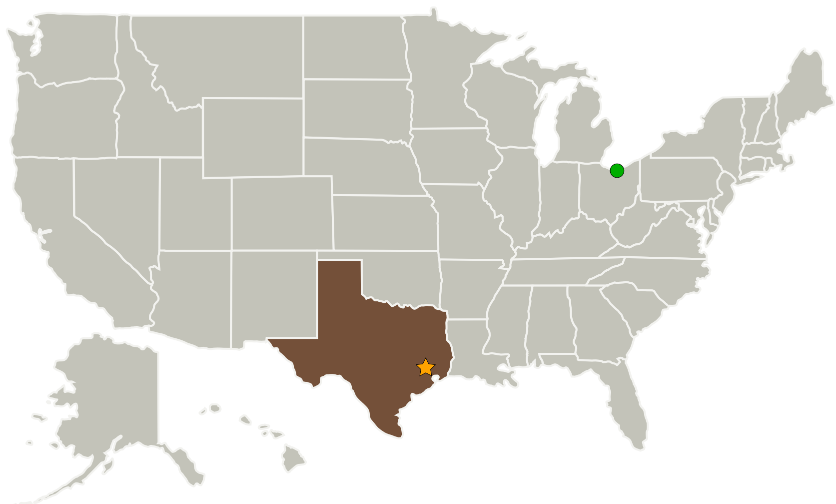
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
●Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio
Lockheed Martin Inc.	Supporting Organization	Industry	Palo Alto, California
University of North Carolina at Charlotte	Supporting Organization	Academia	Charlotte, North Carolina

Primary U.S. Work Locations
Texas

Project Transitions

July 2014: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Project Manager:

Thomas J Williams

Principal Investigator:

Sherry S Thaxton

Co-Investigators:

Jerry G Myers
Simon M Hsiang

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February 2017: Closed out

Closeout Summary: In this reporting period, significant efforts were taken to define the central problem of Spacecraft Optimization Layout and Volume (SOLV), establish a layout evaluation methodology, and outline an overarching model logic map that would govern how the SOLV model would progress from development to deployment. Refinements were made to the Critical Task Volume Database in this year. Revision 2 of the database was released on 11/10/16. Additional volume data were collected in the areas of medical, exercise, extravehicular activity (EVA), body waste, food prep, and group meet and eat tasks. The team also completed a task attribute analysis that “rated” each task against the 16 attributes as identified by SOLV. Some attributes, such as “Gradient Cuboid,” “Operational Adjacency,” and “Share Functional Equipment,” are taken into account as formal constraints in the SOLV code. Rating of attributes for all others was captured in the Task Attributes spreadsheet. Of the 16 task attributes, the team determined that Privacy, Reconfigurability, and Task Time most significantly contributed to whether a task volume could share space or overlap with another. Based on the three ratings for each task, normalized, the team created a concurrency table that defined the overlap allowable for each task. This table was then incorporated into the SOLV code to drive the overlap constraint in the layout generation. Lastly, the team also refined the functional adjacency map initially developed in previous years, to determine task adjacency relationships that would help drive the packing layouts. As part of SOLV’s layout evaluation methodology, the team is deploying surveys across the NASA Subject Matter Expert (SME) community to collect expert opinions and judgement on SOLV’s layout evaluation factors and metrics, in order to establish a factor weighting and scoring system, and drive the model logic for evaluating layout performance. Surveys will be conducted in three main phases: • Factor Priority Surveys ; • Interaction Effects Surveys ; • Manual Layout Evaluation Surveys. To date, we have completed the Factor Priority surveys for non-astronaut SMEs via three main sessions and multiple splinters. Data collection from astronauts will take place in June 2017. All received responses have been processed, submitted through export control, and sent to the University of North Carolina-Charlotte (UNCC) teammates. Data analysis of the survey results at UNCC is ongoing, and initial work indicated that additional post-processing of the data would be required to improve the consistency of the responses and find patterns within responses that were deemed “inconsistent.” Upon completion of the analysis of results from the Factor Priority surveys, top primary design factors could be identified. These factors would then help scope the next two phases of the surveys for interaction effects and manual layout evaluation. In all, 15 subjects from five Subject Matter Expert (SME) groups participated in the Factor survey, generating 28 responses. During this year, the team also made significant progress on the code development for each of the SOLV modules. The final SOLV model must integrate the following modules: • Gradient Cuboid code -- Converts task volume inputs into gradient cuboids and governs how they can interact. • Overlap Packing code -- Generates layouts of the gradient cuboids. • Layout Evaluation code – Establishes the model weighting system and the model response surface via Canonical Correlation Analysis (CANCORR), and contains hard-codes of the Data Envelopment Analysis (DEA) and Choquet Integral (CI) functions that establish the model scoring system for layout evaluation. • Assessment Report – A “scorecard” that provides evaluation results and design information for every volume and layout solution generated by SOLV. This enables the user to compare options and choose the best starting point for his/her design. • Additional code and scripts that integrate the modules to enable smooth model functions from user input to scorecard output. To date, work is ongoing in refini

Technology Maturity (TRL)

Start: **4**
Current: **5**
Estimated End: **5**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  └ TX06.6 Human Systems Integration
    └ TX06.6.3 Habitability and Environment

Target Destinations

The Moon, Mars

Stories

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/38282)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/38283)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/38281)

Project Website:

https://taskbook.nasaprs.com